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AGRICULTURAL EXPERIMENT STATION

THE COMPOSITION OF MAPLE SAP

BY F. W. MORSE AND A. H. WOOD

NEW HAMPSHIRE COLLEGE

OF

AGRICULTURE AND THE MECHANIC ARTS

DURHAM, N. H.

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INTRODUCTION.

During the sugar seasons of 1892, 1893, and 1894, Professors Wood and Morse conducted investigations of problems connected with the maple sugar industry. Owing to the brief period in which maple sap flows freely, it has been impossible to make as complete studies in one season as are necessary for accurate knowedge of the subject, and as seasons also vary, scientific conclusions cannot be drawn from the results of two or three years' experiments. Therefore the following pages contain facts which have been observed, but from which few generalities may be deduced.

While the cane, beet, and sorghum have been extensively investigated and many figures recorded, the results of studies of maple sap, thus far published, are few in number. The theories and observations unsupported by details, are, however, very numerous, and the results stated in the succeeding articles will agree with some and contradict others.

The work has been arranged, for convenience, under appropriate heads.

THE COMPOSITION OF MAPLE SAP

F. W. MORSE AND A. H. WOOD

Note. Professor Wood resigned his position on the Station Staff, November 1, 1894.

All work upon maple sap hitherto published, so far as the writer is aware, is recorded in Bulletin 5, Division of Chemistry, United States Department of Agriculture. The results now mentioned are in several cases closely accordant with those in the work mentioned, and are of value on that account.

In the sixth annual report of this station, a detailed description of these investigations has just been published, therefore in this bulletin only the most noteworthy results will be given.

The variation in percentage of sugar has been found to be wide, and some trees have yielded sap which was hardly worth evaporating. Trees with many branches, and exposed to the full effect of the sun, have been found to give the richest saps, and trees with small tops in a thick grove, or much shaded, have given the poorest sap. The amount of sugar in the sap has not depended upon variety of maple, since soft maples have yielded both as high percentages of sugar, and as low as rock maples.

The sap toward the close of the season has shown neither as much sugar, nor as much solids as at the beginning of the season. This change has not taken place at a uniform rate, but instead there have been fluctuations up and down.

VARIATION IN SAP FROM DIFFERENT TREES, MARCH 31, 1892.

	Description of Tree.	Per cent. Saccharose.
A.	Rock maple, with small top, in a grove	1.30
C.	Rock maple, with medium top, in a grove beside cart path	2.30
E.	Rock maple, with large, wide top, surrounded by tall, young pines	2.80
L.	Rock maple, large pasture shade tree	5.60
F.	Soft maple, with many small branches, in open ground	4.00
G.	Soft maple, with wide-spread top, surrounded by pines	2.50

VARIATIONS IN SAP FROM DIFFERENT TREES. 1893.

Description of tree.	Date.	Saccharose.	Total Solids.
2. White maple, situated in a group of maple and hickories; tall, with medium top....	March 22	2.80	
	" 25	2.20	
	" 30	2.90	3.00
	April 13	2.80	
4. Rock maple, near the above tree and similar in size and form. Tapped in two places. Average of results given for each date	March 22	3.40	
	" 25	3.25	
	" 30	2.88	
	April 1	2.75	3.01
	" 16	2.45	2.72
6. White maple, shade tree by road side, medium size, many branches, well developed	March 22	4.90	5.04
	" 25	3.30	
	" 27	3.40	3.61
	" 30	2.90	3.37
	April 1	3.00	3.21
7. Rock maple, shade tree by road side, taller and larger than 9, but similarly proportioned	March 22	3.20	
	" 25	2.80	
	" 27	3.10	
	" 30	2.90	
	April 1	2.90	
9. Rock maple, shade tree by road side. About the same size as 10.	March 22	4.00	4.17
	" 25	3.40	
	" 27	4.00	
	" 30	3.40	3.65
	April 13	2.50	
	" 16	2.21	
	" 20	2.35	2.40

The variation in composition of sap from different sides of a tree, has not been found to be wide nor constant. Two trees showed a decidedly higher percentage of sugar from the north side, one tree gave the advantage to the south side, while a fourth tree gave nearly equal percentages to both north and south sides.

COMPOSITION OF SAP FROM DIFFERENT SIDES OF A TREE, 1892 and 1893.

Description of Tree.		Date.	Saccharose.	Total Solids.
		1892.		
b. Rock maple, in a grove, tall with small top.	N. W. side.	Mar. 27	2.25	2.66
	S. W. side.	" 27	1.95	2.12
		1893.		
2. White maple, in a group of trees, tall with medium top.	N. side.	Mar. 25	1.70	
		" 30	2.60	
		Apr. 13	2.20	
	S. side.			
		Mar. 25	2.20	
		" 30	2.90	
		Apr. 13	2.80	
4. Rock maple, near (4.) and similar in size and form.	N. side.	Mar. 22	3.40	
		" 25	3.40	
		" 30	2.75	3.01
		Apr. 1	2.80	
		" 16	2.51	2.79
	Average.	.....	2.97	
	S. side.	Mar. 22	3.40	
		" 25	3.10	
		" 30	3.00	
		Apr. 1	2.70	3.01
		" 16	2.39	2.64
	Average.	.....	2.92	
12. Rock maple, in an open field, branches low and wide-spread.	N. side.	Apr. 8	2.80	
		" 10	2.95	
	S. side.	Apr. 8	2.40	
		" 10	2.35	
	E. side.	Apr. 8	2.60	
		" 10	2.60	
	W. side.	Apr. 8	2.20	

It has been claimed that the outer wood of the maple yields a richer sap than the inner wood. To test the correctness of this opinion, tree 13 was tapped with two holes as near together as possible ; one hole being bored diagonally in order to keep near the bark, and the other bored toward the centre of the tree. Each hole was bored to the same depth on the bit. The result of this experiment was contrary to the above claim. Trees 8

and 10, which had been flowing since March 22 from holes 1¼ inches deep, were then bored to a depth of 2½ inches in the same holes on April 9. Samples of sap from each tree were taken before and after the increase in depth of holes. The results were the same as with tree 13, and furthermore, the percentages of sugar continued to remain higher for the balance of the season than they were before the experiment.

On April 20 two more trees, *o* and *p*, were tapped by boring a hole of large diameter to the depth of 1½ inches and then continuing with one of small diameter to an additional depth of 2 inches. The sap was collected from the outer and inner wood by means of a double spout consisting of one tube within another. The results this time agreed with the above claim.

In 1894, two trees, *r* and *s*, were tapped in a similar manner, with the exception that the outer hole was carried to a depth of 2⅞ inches, and the inner hole 2⅞ inches further. Again the results agreed with the claim.

VARIATION IN COMPOSITION OF SAP FROM OUTER AND INNER WOOD. 1893.

Description of Tree.	Date.	Per cent. Saccharose.	Total Solids.
Tree 8. Rock maple shade-tree by road side. Tapped first on March 22 to a depth of 1¼ inches. On April 9, after collecting the flow of sap, the hole was extended to the depth of 2½ inches.....	Mar. 22	3.20	3.52
	" 25	2.90	
	" 27	3.20	
	" 30	2.60	
	Apr. 1	2.50	2.86
	" 9	1.65	1.81
Hole bored deeper.....	" 9	2.05	2.34
	" 13	2.06	
	" 16	2.03	2.23
	" 20	1.98	2.18
Tree 10. Rock maple shade-tree by road side. Tapped in the same manner as 8, and on the same dates.....	Mar. 25	4.00	
	" 27	4.60	4.96
	" 30	3.30	4.10
	Apr. 1	3.50	4.37
	" 9	3.45	
Hole bored deeper.....	" 9	3.75	
	" 13	3.73	
	" 16	3.68	4.23
	" 20	3.72	4.16
Tree 13. Large rock maple in an open field. Tapped with two holes near together. Hole bored diagonally, keeping near the bark..	" 8	2.85	
Hole bored toward centre, 4 inches in depth.....	" 8	3.00	

VARIATION IN COMPOSITION OF SAP FROM OUTER AND INNER WOOD. 1893–1894.

Description of Tree.	Date. 1883.	Outer Wood. Saccharose.	Outer Wood. Solids.	Inner Wood. Saccharose.	Inner Wood. Solids.
o. Large rock maple in an open field. Tapped by boring a hole 1″ in diameter and 1½″ deep, and continuing the tapping with a ½″ hole, 2″ in depth.....	Apr. 20	2.45	2.53	1.98	2.13
p. Small rock maple growing in a wood. Tapped as above	" 20	2.08	2.25	1.92	1.93
	" 25	2.00	2.17	1.85	
	" 26	2.10	2.30	1.75	1.94
	1894.				
r. Tall maple in a group of trees in open field; 12″ in diameter. Tapped with hole 13-16″ diameter and 2⅞″ depth, continued by a hole 6-16″ diameter and 2⅝″ depth.....	Mar. 13	2.66	2.81	1.90	2.04
	" 17	2.64	2.80	2.36	2.45
	" 22	2.58	2.74	2.05	2.13
	" 30	2.55	2.65	1.86	1.95
s. Rock maple in grove on south slope of a low hill. Diameter about 12″.....	Mar. 17	1.99	2.07	1.48	1.54
	" 22	1.86	1.91	1.45	1.56
	" 31	1.93	1.98	1.51	1.59

The variations in richness of sap due to the manner of tapping, have not yet been found sufficiently wide to justify any method which will lessen the flow of sap. By comparing the variations in composition with those of sap-flow given in Bulletin 24, it will be noticed that the methods giving the richest saps yielded the least in quantity.

SOME NOTES ON MAPLE SYRUP AND SUGAR

BY A. H. WOOD AND F. W. MORSE

In 1892 and 1893, some work was done in making maple syrup, but as has been said with regard to sap-flow, the seasons are short and often capricious, necessitating many repetitions of results before laws can be definitely laid down.

The spring of 1892 was a peculiar one, because after the sap had flowed for a period of about two weeks, warm weather ensued which caused the buds to start and stopped the bleeding; and at the end of ten days, the temperature fell, a succession of cold nights occurred, growth was checked and the flow of sap was renewed. The syrups of this second period were scarcely different in composition from those of the first period, except the very earliest.

Experiments in letting sap stand for several days before boiling, filtering sap, and rapid and slow evaporation had no decisive effect on the composition of the syrup.

The syrups from soft maples were somewhat inferior to those from rock maples both in color and flavor.

Delay in boiling sap did not seem to affect the color of the syrup, but injured its flavor. Sap that was kept five days and then boiled gave one of the lightest colored samples produced.

The rapidity of boiling had little influence on the color, samples of syrup from saps that we allowed to slowly simmer away, being as light colored as those from similar saps boiled rapidly.

The lightest colored samples were produced by boiling a quantity of sap until finished, without addition of fresh sap.

One sample produced by boiling about two quarts of sap in a large glass beaker until it was thick syrup, without addition of sap and without skimming, had little more color than the sap from which it had been made. This sap was from covered buckets and was thoroughly strained through cloth before boiling.

Sap filtered through quartz sand produced a syrup in no way superior to the preceding, while one filtered through bone black lost almost entirely the characteristic maple flavor.

Sap mixed with rainwater gave a syrup objectionably dark colored.

To produce a light colored and fine flavored syrup requires that the sap be kept as free as possible from all impurities and throughly strained; that it be reduced to syrup with the least manipulations possible, taking care in every part of the process that neither sap nor syrup comes in contact with surfaces that may in any way injure their quality.

COMPOSITION OF MAPLE SYRUP. 1892.

Description of Sample.	Saccharose.	Solids	Reducing Sugars.	Ash.	Purity.
1. First run, March 26	69.6	71.0		0.57	98.02
2. " " "	70.2	71.5	0.22	0.68	98.17
4. One week later, April 2	65.8	68.4	0.23	1.10	96.18
8. " " " "	41.0	43.9	0.14	0.46	93.40
9. Just before warm period, April 4	66.0	70.3	0.13	1.15	93.87
10. " " " " "	66.4	70.4	0.14		94.32
16. Just after warm period, April 14	62.2	65.8		1.04	94.54
17. " " " "	60.1	64.9	0.18	1.15	92.62
24. Late run, April 27	57.9	62.7	0.27	1.67	92.34
5. White maple, April 2	68.9	70.8	0.14	0.60	97.31
21. " " April 16	48.2	50.1	0.13	0.60	96.20
20. " " April 18	47.8	47.8	0.12	0.59	96.56
7. Run April 1. Boiled at 221° F.	67.5		0.19		
11. " Evaporated at low temperature 3 days, then boiled	56.4		0.09		
13. Same as 11, after standing 4 days	58.1		0.15		
14. Same as 7, after standing 5 days	65.7		0.23		
17. Run April 14. Boiled at 217° F.	60.1		0.18		
18. " Filtered through bone black and then boiled	63.1		0.25		
19. Run April 14. Filtered through quartz sand and then boiled	56.6		0.15		
22. Run April 14. Boiled at 215° F.	43.6		0.18		

COMPOSITION OF MAPLE SYRUP. 1893.

Syrup.	Date.	Sac-cha-rose.	Total Solids.	Reducing Sugars.	Ash.	Specific Gravity.	Purity.
0. White maple.....	Mar. 25	65.4	68.0	0.225	0.407	1.3289	96.18
13. Rock maple.....	" 25	61.8	67.2	0.200	0.670	1.3270	91.96
12. Rock and white..	" 30	58.5	62.8	.....	.....	1.3081	93.15
14. Rock maple. Soured sap.....	" 30	58.2	63.6	0.540	.....	1.3135	91.49
15. Rock maple. Boiled with frequent addition of cold sap.....	Apr, 10	57.2	63.1	0.070	0.720	1.3079	90.65
16. From same trees as 15. Boiled without adding fresh sap.....	" 10	61.9	68.5	0.216	.....	1.3371	90.36

As a preliminary to the investigation of problems connected with the maple sugar industry, several samples of sugar were obtained from various sources and analyzed in order to gain some knowledge of the composition of the article.

COMPOSITION OF MAPLE SUGAR. 1891.

Sample.	Saccha-rose.	Solids.	Reducing Sugars.	Ash.	Purity.
1. Dry sugar.....	93.3	98.3	0.63	0.99	94.9
3. Dry sugar, very light color.....	87.3	95.4	2.69	1.11	91.5
4. Dry sugar, very light color.....	90.5	96.7	0.92	1.19	93.6
5. Dry sugar, very dark color.....	85.2	96.4	4.51	1.16	88.4
6. Dry sugar.....	88.1	95.5	2.76	0.91	92.2
7. Dry sugar.....	91.7	95.6	1.16	0.88	95.9
11. Dry sugar, very light color.....	93.7	98.6			95.0
2. Cake sugar, last run.....	76.8	91.0	7.03	1.23	84.4
8. Cake sugar, soft.....	83.6	88.6		0.92	94.3
9. Cake sugar, medium.....	85.9	90.3		1.04	95.1
10. Cake sugar, hard.....	86.0	92.3		0.88	93.2

The dry sugars contained more solids than cake sugars but the purity co-efficient was as high in one form as in the other. Dark sugars contained less saccharose and more reducing sugars than light sugars and had a much lower purity coefficient.

In 1892 a few samples were prepared under different conditions, and the analytical results are given below.

COMPOSITION OF MAPLE SUGAR. 1892.

Sample.	Finishing Temperature.	Saccharose.	Solids.	Purity.
1. Early run. Very light, soft fine grain	230° F.	82.9	84.9	97.6
2. Early run. Light, coarse grain	235° F.	85.9	88.6	96.9
3. Early run. Clarified. Golden, medium grain	240° F.	84.8	88.0	96.3
4. Early run. Clarified and stirred. Finer and lighter than 3	240° F.	85.6	88.5	96.7
5. Early run. Clarified and stirred until cold. Fine	240° F.	91.5	94.8	96.5
6. Late run. Clarified. Burned slightly; dark	240° F.	82.7	88.0	93.9
7. Late run. Clarified and stirred. Burned; lighter than 6	240° F.	83.9	89.5	93.7
8. Syrup had fermented and become slightly acid		58.1	89.0	65.3

Clarifying the syrup and stirring it while boiling improved the color, and the stirring increased the amount of sugar and solids. Numbers 6 and 7, prepared in the same manner as 3 and 4, but from a later flow of sap, yielded the same percentage of solids, but considerably less sugar and burned slightly. This result is similiar to results obtained at the Vermont Experiment Station. (Bulletin 26.)

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Bulletins 1-48